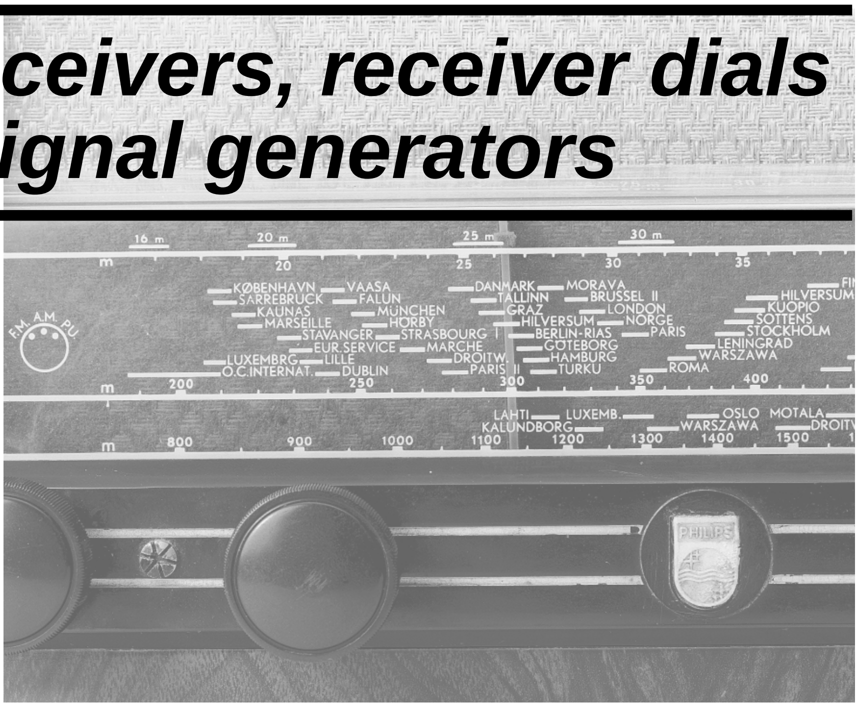
RF marker generator

calibrate receivers, receiver dials and signal generators



Anyone involved in the construction of radio receivers and associated equipment will have felt the need for some means of producing an accurately calibrated dial. The ability to confidently set the tuning to a particular frequency is often half the battle when searching for a weak transmission, and greatly increases the pleasure of using a receiver of any kind. The calibrator described here relies on a quartz crystal to determine and hold constant the frequency of the oscillator providing the marker signals.

Design by Raymond Haigh

Early instruments of this kind often incorporated two crystals, one cut to resonate at 1 MHz, the other at 100 kHz, and the fundamentals and harmonics of these frequencies were used to calibrate receivers and test gear up to, and beyond, 30 MHz.

The development of the integrated circuit, in particular the production of binary and decimal counter ICs, made it possible to use only one crystal, cut to resonate at a higher frequency (often 2 or 4 MHz), and to divide the frequency down in order to provide markers for long and medium waves, and for the fine sub-division of the dial.

When attempting to calibrate the dial of a short-wave receiver using only a crystal standard, difficulty can be encountered in identifying the particular harmonic of a 1 MHz fundamental. If a 4 MHz crystal is used the position is much easier, but confusion can still arise as calibration progresses into the upper reaches of the HF spectrum.

In order to avoid this, the unit described here has been designed around an 8 MHz crystal. With harmonics at 16, 24 and 32 MHz, virtually unmistakable markers are produced throughout the HF bands, and it is a comparatively simple matter to calibrate up or down from these points by means of lower frequency signals produced by the division of the crystal fundamental.

Most crystal markers make no provision for the modulation of the signal. High performance receivers incorporating a BFO (beat frequency oscillator) can produce an audible tone from an unmodulated carrier, but with domestic superhets there will be no clear audible indication that the marker signal has been tuned-in. Ironically, it is often the listeners who are trying to get the most out of simpler receivers who have the greatest need for some means of improving tuning accuracy. Accordingly, provision is made for the optional modulation of the marker signals.

THE CIRCUIT

The full circuit of the unit is given in **Figure 1**. It is based on low-cost, CMOS (complimentary metal oxide semiconductor) logic gate ICs. An inexpensive 8 MHz crystal determines the basic frequency of oscillation with a high degree of accuracy and stability.

IC5 contains four two-input NOR gates. Strapping the inputs of each gate together produces four inverting amplifier stages. One of these, IC5a, is used as the RF oscillator, with the frequency of oscillation determined by quartz crystal X1. In this circuit, the crystal presents an inductive reactance at the operating frequency, and it resonates with loading capacitors, C1 and C2. C2 is adjustable, and the frequency of oscillation can be set, by reference to an external standard, at precisely 8 MHz. DC negative feedback, provided by R1, stabilises the operating conditions of the stage, and IC5b buffers the output.

IC5c and IC5d are connected as an R-C oscillator, the values of R5-R6 and C5 being chosen to give a frequency of oscillation in the region of 1 kHz. This audio tone is used to modulate the RF output of the marker generator.

The buffered output of the oscillator is applied to the clock input of IC1, a dual bistable flip-flop. This device allows alternate pulses to pass, thereby dividing the crystal oscillator frequency by two. The resulting 4 MHz marker at pin 1 is fed to the second clock input, and a 2 MHz signal is available at pin 13. This process is repeated with IC2 in order to produce 1 MHz and 500 kHz markers.

The 1 MHz signal is applied to clock input of IC3a, a dual decimal counter. The first stage of this IC divides the 1 MHz input by 10 to give 100 kHz. This signal is applied to the second stage for further division by 10 to produce a 10 kHz marker.

50 kHz and 25 kHz markers are useful when calibrating the long, medium and lower HF scales of a receiver, and to provide these the 100 kHz output from IC3a is applied to another dual bistable, IC4.

Transistor T1 acts as a modulator. Configured as an emitter follower, its base presents a moderately high impedance to the incoming signal from the divider ICs, the required marker being selected by rotary switch, S2. A low-impedance output is developed across emitter resistance, R2-R3. Socket K2 supplies a relatively low output level (20-50 mV) which may be safer for direct rather than inductive coupling to receiver inputs.

Switch S1 enables the 1-kHz oscillator when a modulated output is required.

With CMOS devices, propagation delay (the time taken for the output to change in response to a change of state at the input) is particularly dependent on supply voltage. IC5 and IC1, located at the start of the chain of dividers, are working fairly close to their maximum clock frequency, and the lowest supply voltage for reliable operation is 12 V.

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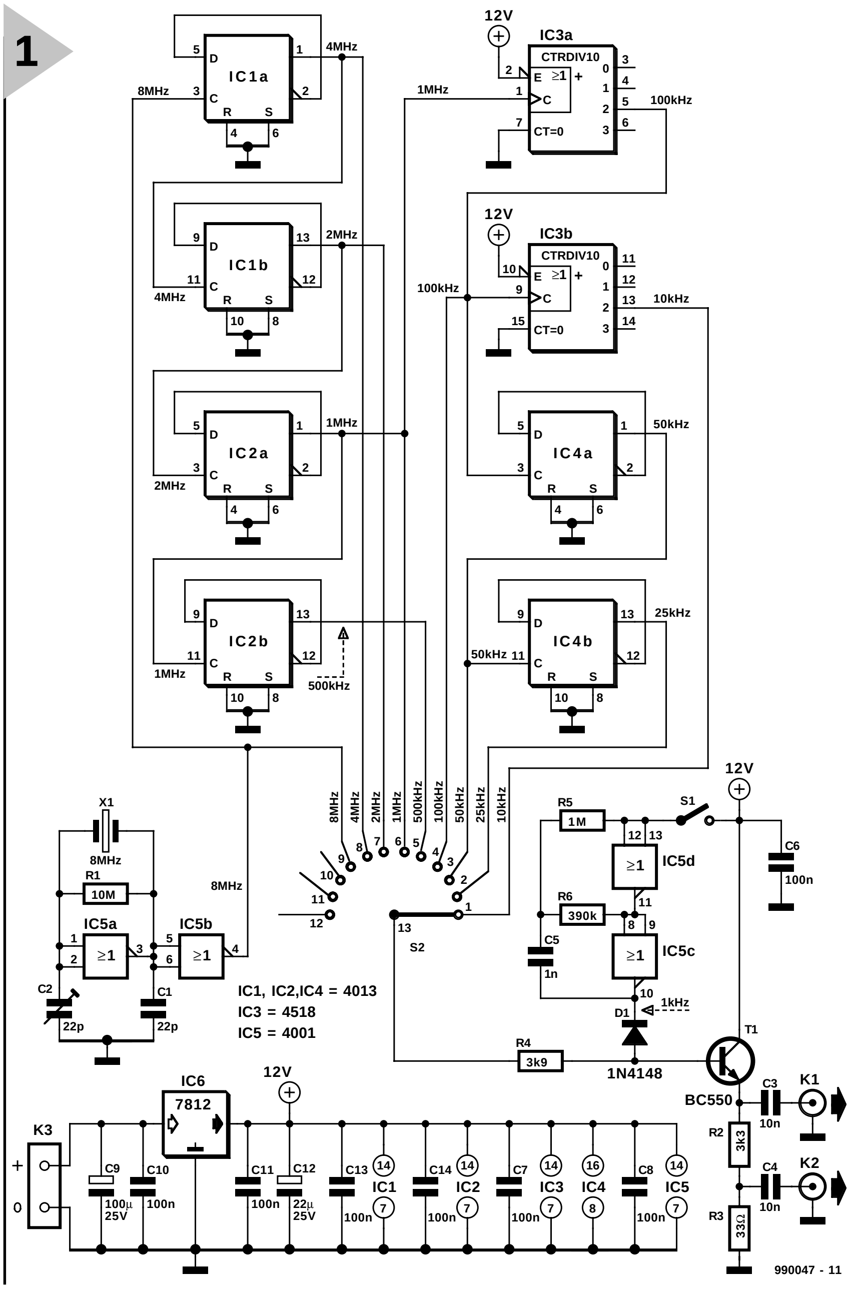

Figure 1. Circuit diagram of the RF marker generator.

Although crystal oscillators are renowned for their stability, operating frequency is shifted, to some small extent, by changes in the amplifier's supply voltage. Regulation of the supply voltage will therefore enhance the performance of the unit. Power is accordingly derived from two 9-volt PP3 batteries connected in series to give a nominal 18 V supply, which is dropped to the required 12 V as well as regulated by IC6. Bypass capacitor C12 shunts any electrical noise developed by the regulator to the ground rail.

Current drain with fresh batteries is in the region of 35 mA and this falls to around 25 mA when they reach the end of their useful life. Whilst this is not an excessive current demand on a PP3 battery, equipment of this kind tends to be operated for lengthy periods, and provision is made in the prototype unit for powering it from a bench supply or an inexpensive (12-volt dc) mains adaptor.

CONSTRUCTION

All of the components, with the exception of switch S1 are mounted on a PCB. **Figure 2** shows the component mounting plan (overlay) and copper track layout. The board shown is not available ready-made.

Although the CMOS IC's are fitted with static protection diodes, these cannot be relied upon to prevent damage, and appropriate precautions against ESD should be taken when unpacking and installing the devices. Work on a grounded bench mat, and never insert or withdraw a CMOS IC, or work on the PCB, with the power supply connected.

IC sockets are fitted to permit rapid substitution checking (it is not

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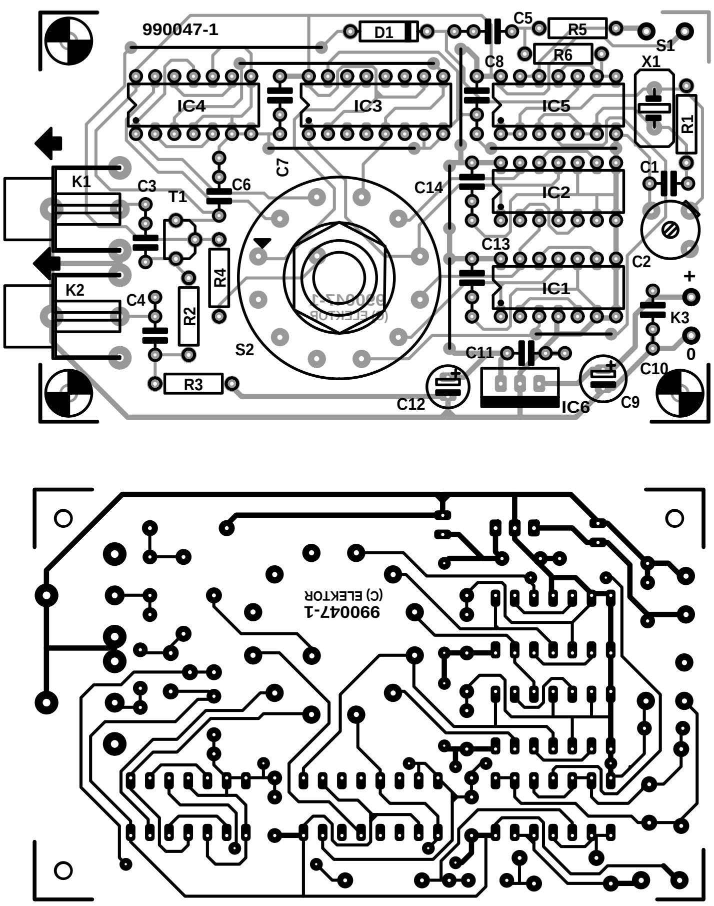
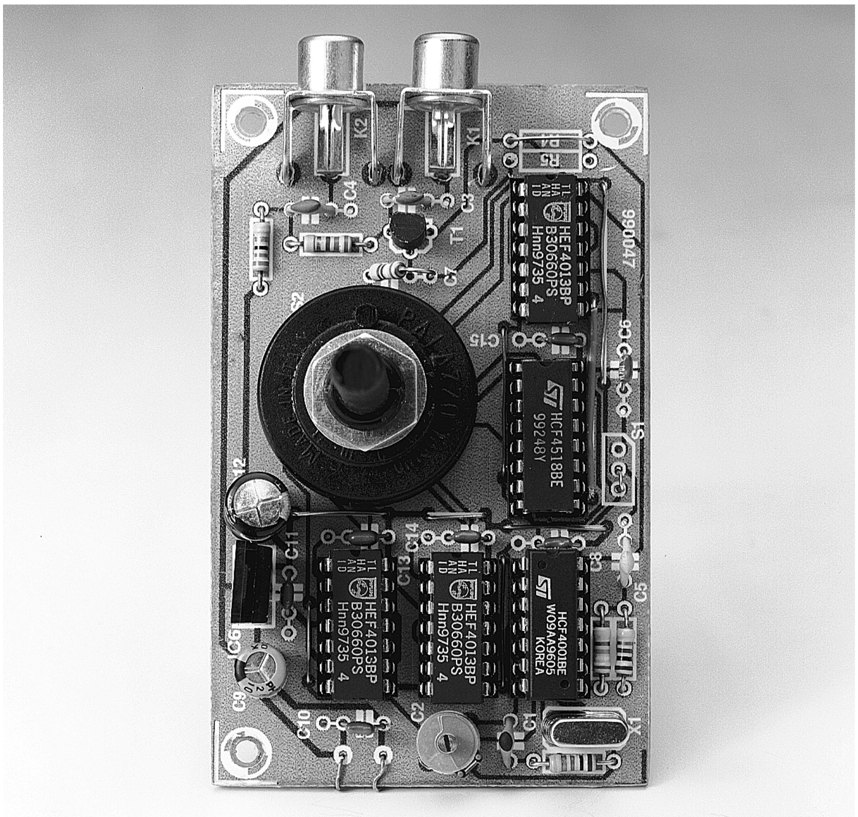


__Figure 2. PCB artwork (board not available ready-made).__

__Figure 3. Finished PCB, ready for mounting into the enclosure.__



COMPONENTS LIST

Resistors:
R1 = 10 MΩ
R2 = 3kΩ3
R3 = 33 Ω
R4 = 3kΩ9
R5 = 1 MΩ
R6 = 390 kΩ

Capacitors:
C1 = 22 pF
C2 = trimmer, 22 pF
C3,C4 = 10 nF
C5 = 1 nF
C6,C7,C8,C10,C11,C13,C14 = 100 nF
C9 = 100 µF 25V radial
C12 = 22 µF 25 V radial

Semiconductors:
D1 = 1N4148
T1 = BC550
IC1,IC2,IC4 = 4013
IC3 = 4518 (see text)
IC5 = 4001
IC6 = 7812

Miscellaneous:
X1 = 8MHz crystal
K1,K2 = cinch socket, angled, PCB mount
S1 = on/off switch
S2 = 12-way 1-pole rotary switch, PCB mount
K3 = 2 solder pins

Components

All of the ICs and semiconductors, with the exception of the low current LED, are listed in JAB Electronics' catalogue (JAB, PO Box 5774, Birmingham, B44 8PJ). This firm can also supply the other components. Maplin retail all of the parts. They offer two variants of the 4518, and it is the device they list as HCF4518BEY dual BCD counter which is required for this project. Cirkit can supply everything except the 4518 IC.

unknown for ICs of this kind to be faulty when supplied) and minimise the possibility of damage during installation.

Finally, check your work against **Figure 3**.

TESTING

It is a good idea to check the functioning of the unit before the whole assembly is enclosed within a case.

First of all, check the PCB for poor soldered joints and bridged copper tracks. Check the orientation of the ICs and other semiconductors, in particular the voltage regulator IC: if this is connected into circuit wrongly, the full supply voltage could appear across the CMOS devices.

Connect the unit to batteries or a bench power supply. Current consumption with an 18 V supply to the regulator should be in the region of 35 mA. Check that the output from the regulator is 12 V.

If a frequency meter or an oscilloscope is available, use it to check the various spot frequencies. Otherwise, use a radio receiver to ensure that the circuit is functioning (guidance on injecting the signal into a receiver is given later).

ADJUSTMENT AND USE

If an accurate frequency counter is available, inject the 8 MHz marker (modulation switched off) and adjust C2 to 'pull' the crystal to the exact frequency.

If a radio receiver is to be used to set the calibrator, tune it to an appropriate transmission; e.g., Deutsche Welle, a 500-kW transmission on 6 MHz from Germany. Inject the highest possible marker spot frequency into the receiver, and adjust C2 for zero beat with the transmission. As the two frequencies draw closer, the pitch of the audible beat note emitted by the receiver will decrease to a slow fluttering and then cease (zero beat) when the harmonic of the marker frequency exactly matches the frequency of the distant transmitter. The 1 MHz marker will, of course, have to be used for transmissions on an odd number of MHz, but 2 MHz can be used for the German station radiating on 6 MHz.

A short screened lead on K2 can be used to connect the output of the marker generator to the equipment to be calibrated, but a length of single flex on K1, placed near the receiver's aerial terminal, will usually be all that is required to secure adequate injection. Always keep injection levels as low as possible in order to minimise spurious responses within the receiver. Note that superhets generate images of the received signal, the most troublesome being spaced at twice the receiver's intermediate frequency from the transmission.

If the receiver is of the communications type, switch on the BFO and tune it to zero beat with unmodulated markers. This technique can also be used for the calibration of simple regenerative receivers if the regeneration or 'Q' multiplier control is advanced until the receiver is just oscillating. If the receiver is a domestic superhet or a TRF (Tuned Radio Frequency) receiver without regeneration, the marker signals will have to be modulated in order to produce an audible tone.

Harmonics of all the markers extend upwards through the HF spectrum, and confusion will be avoided if the highest possible marker frequency is used to start the calibration process: e.g., begin by injecting a 1 MHz marker on medium waves (the band does not extend far enough to contain its harmonic on 2 MHz), and start with the 4 or 8 MHz markers as the calibration progresses through the short wave bands.

When these datum points have been established, work away from them using a lower frequency marker. On medium waves, 100 kHz would be appropriate, followed by 50 then 25 kHz in order to further sub-divide the scale. If the dial is large, 10 kHz could be injected, rather than 25 kHz, in order to produce a finer calibration.

The calibrator can, of course, be used as a means of accurately setting the tuning of a receiver with a poor or badly calibrated dial to the frequency of a particular transmitter.

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